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(54) **ANTI-ROTATION DEAERATOR OUTLET DIFFUSER**

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(52) **U.S. Cl.**
USPC **95/261**; 96/212; 96/219; 96/187; 184/6.23

(58) **Field of Classification Search**
USPC 95/261; 96/211, 219, 210, 187, 96/212, 209; 184/6.23
See application file for complete search history.

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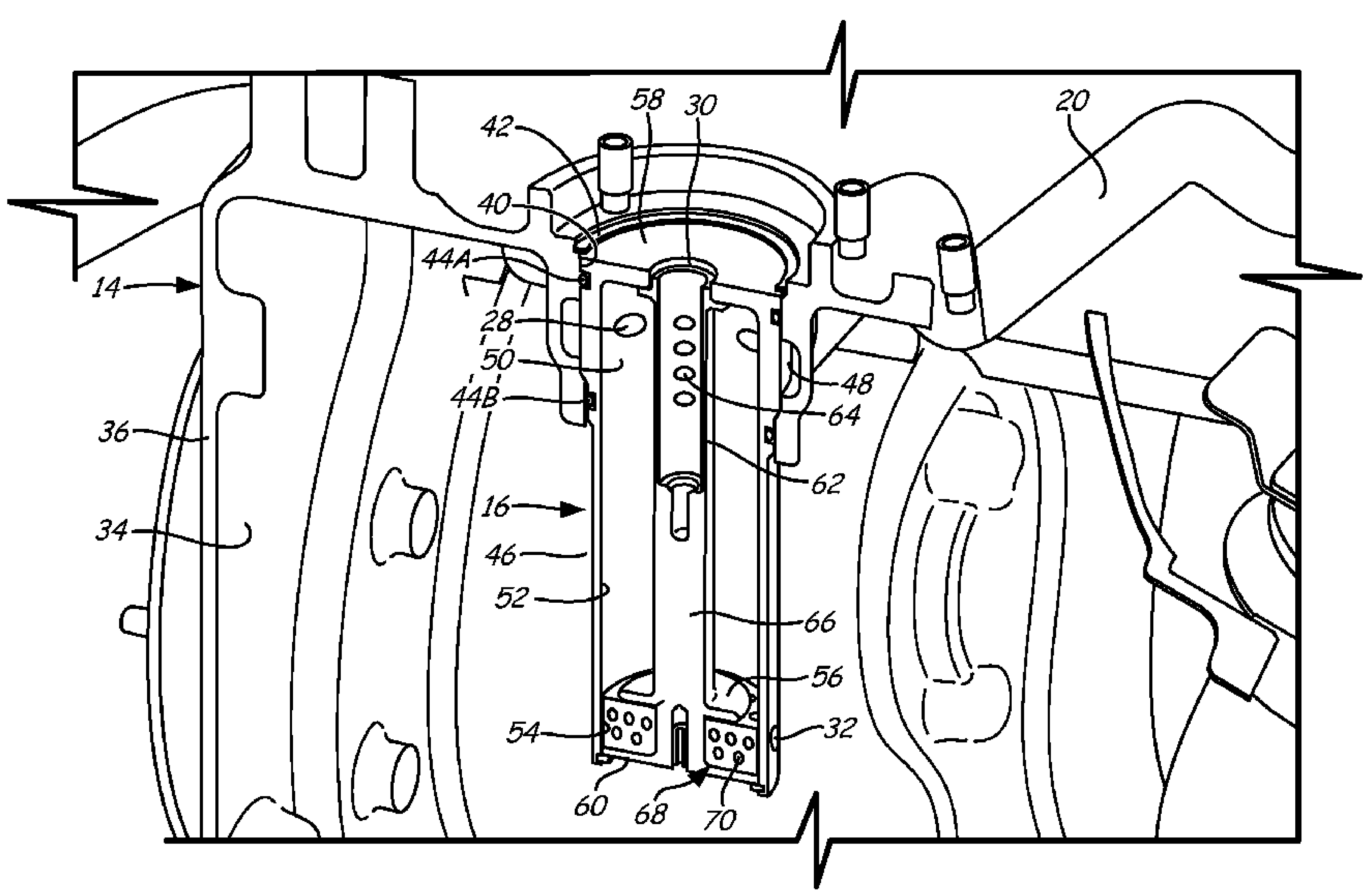
(57) **ABSTRACT**

A deaerator includes a case defining a vortex chamber, a fluid inlet for allowing a mixture of lubricating liquid and air to pass through the case into the vortex chamber, an air outlet for allowing air flow out of the deaerator, and a liquid outlet for allowing lubricating liquid flow out of the deaerator. A porous diffuser is positioned proximate the liquid outlet. A plate is positioned adjacent the porous diffuser and has a first surface in contact with the porous diffuser.

20 Claims, 5 Drawing Sheets



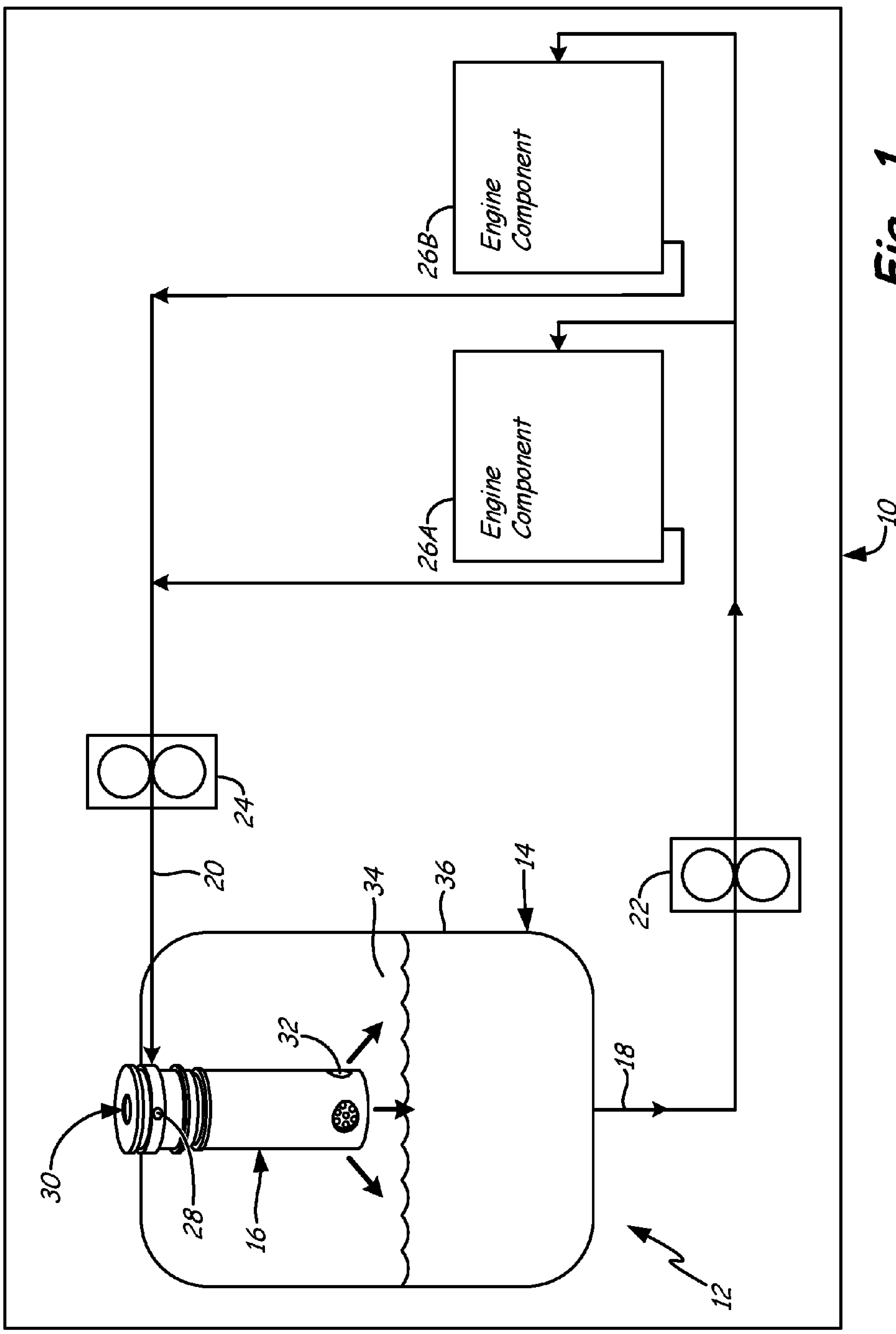

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Fig. 1

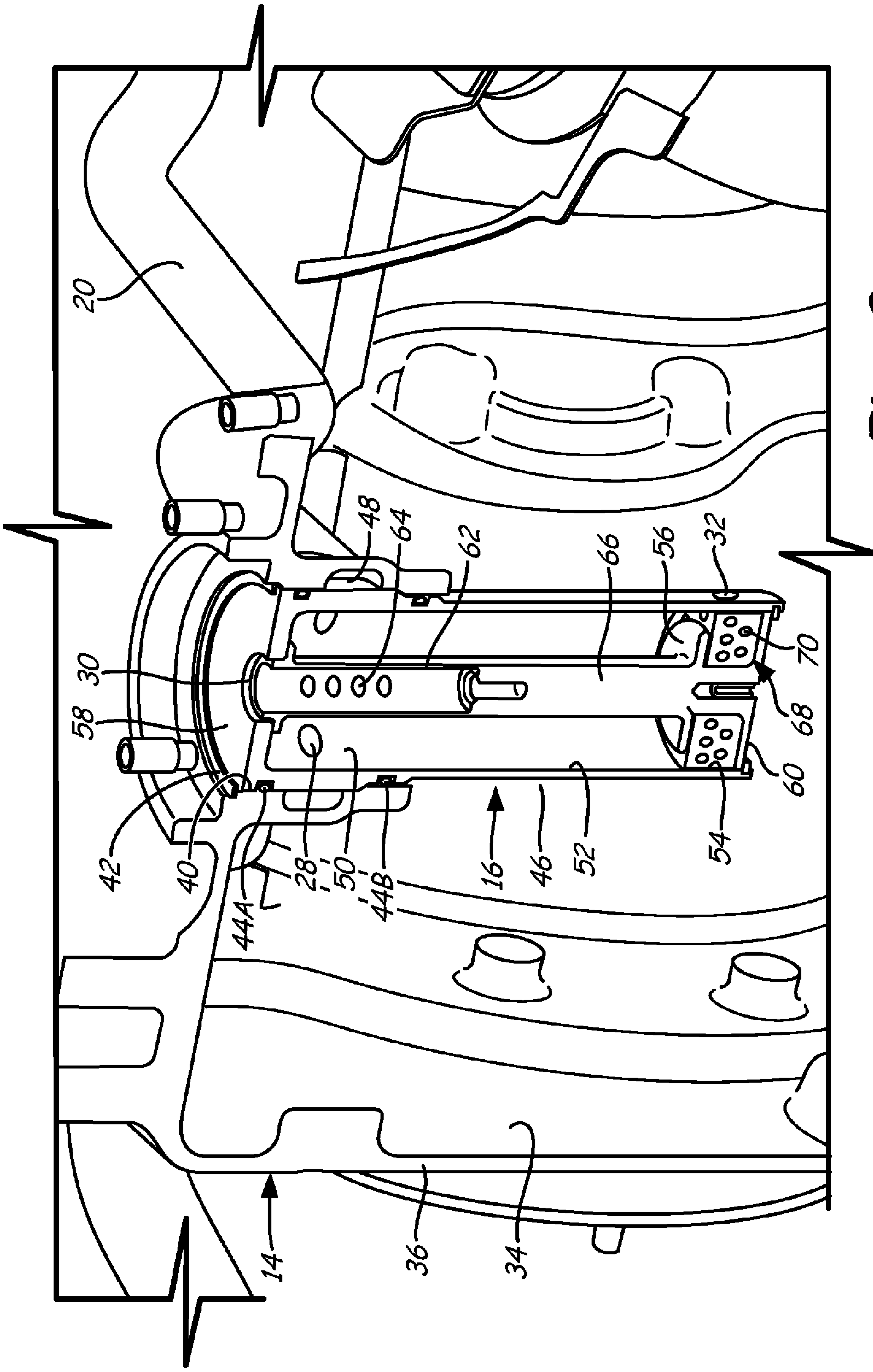
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Fig. 2

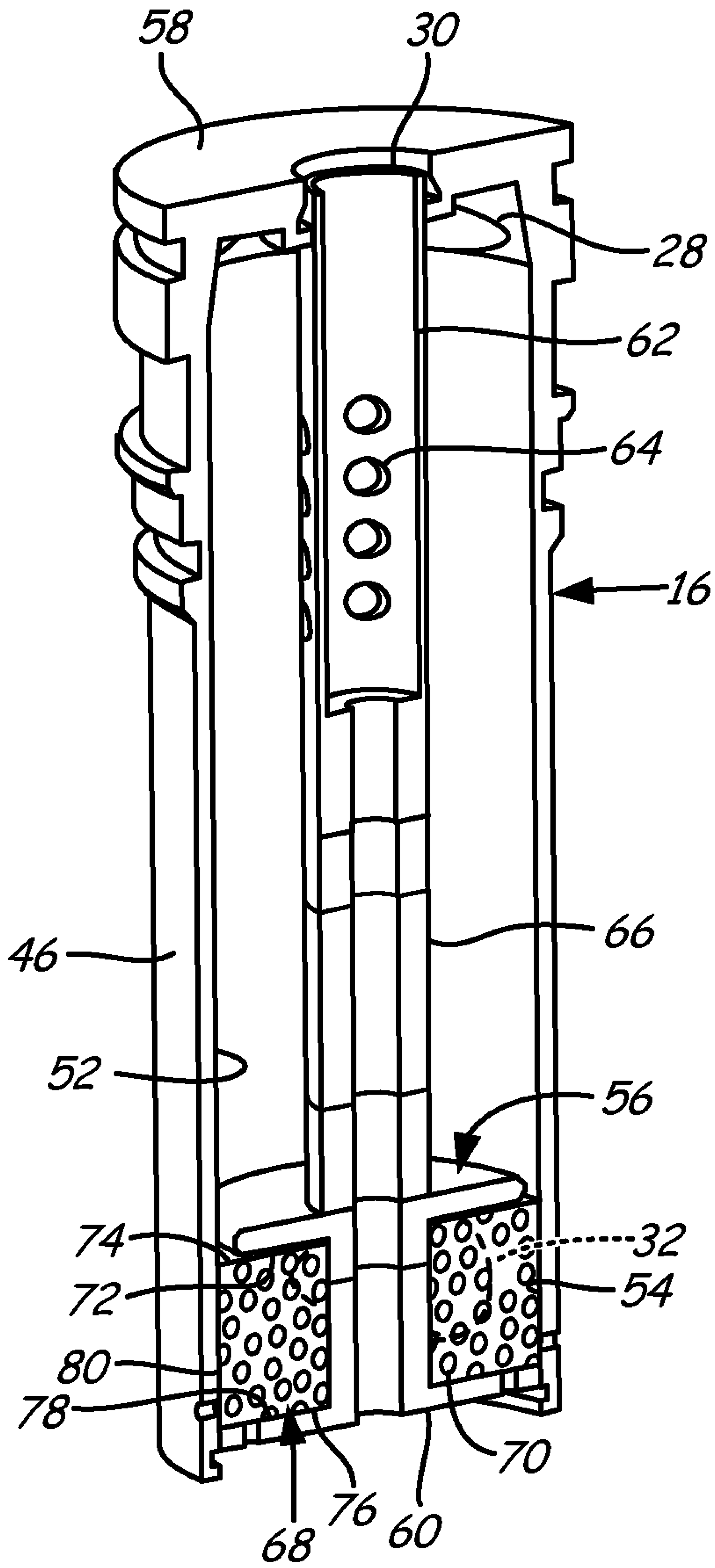

Fig. 3

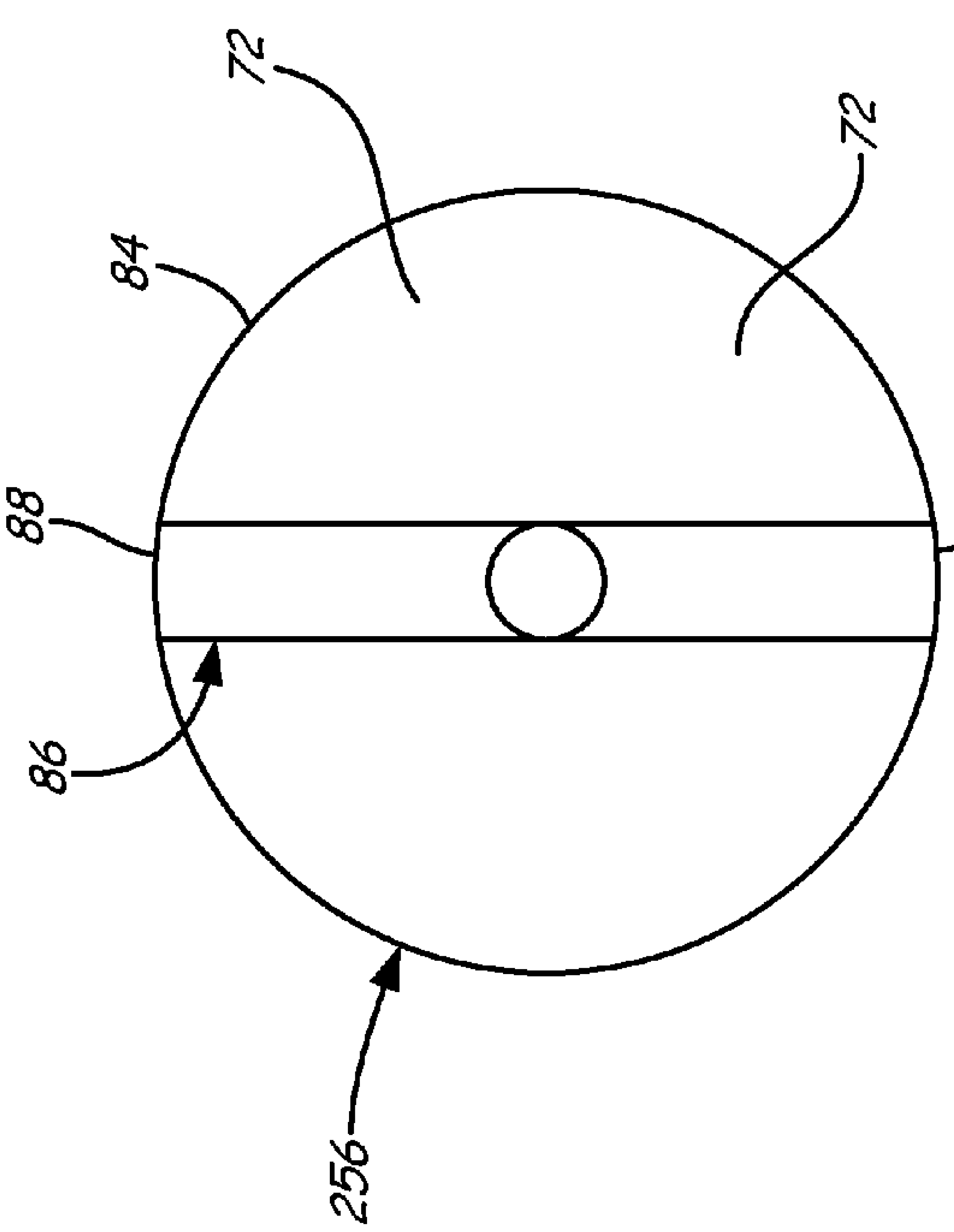

Fig. 5A

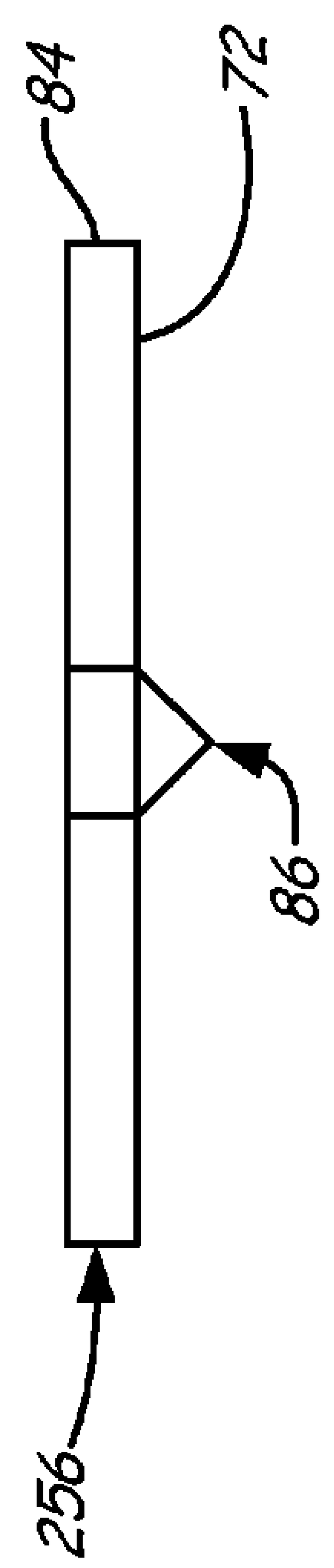

Fig. 5B

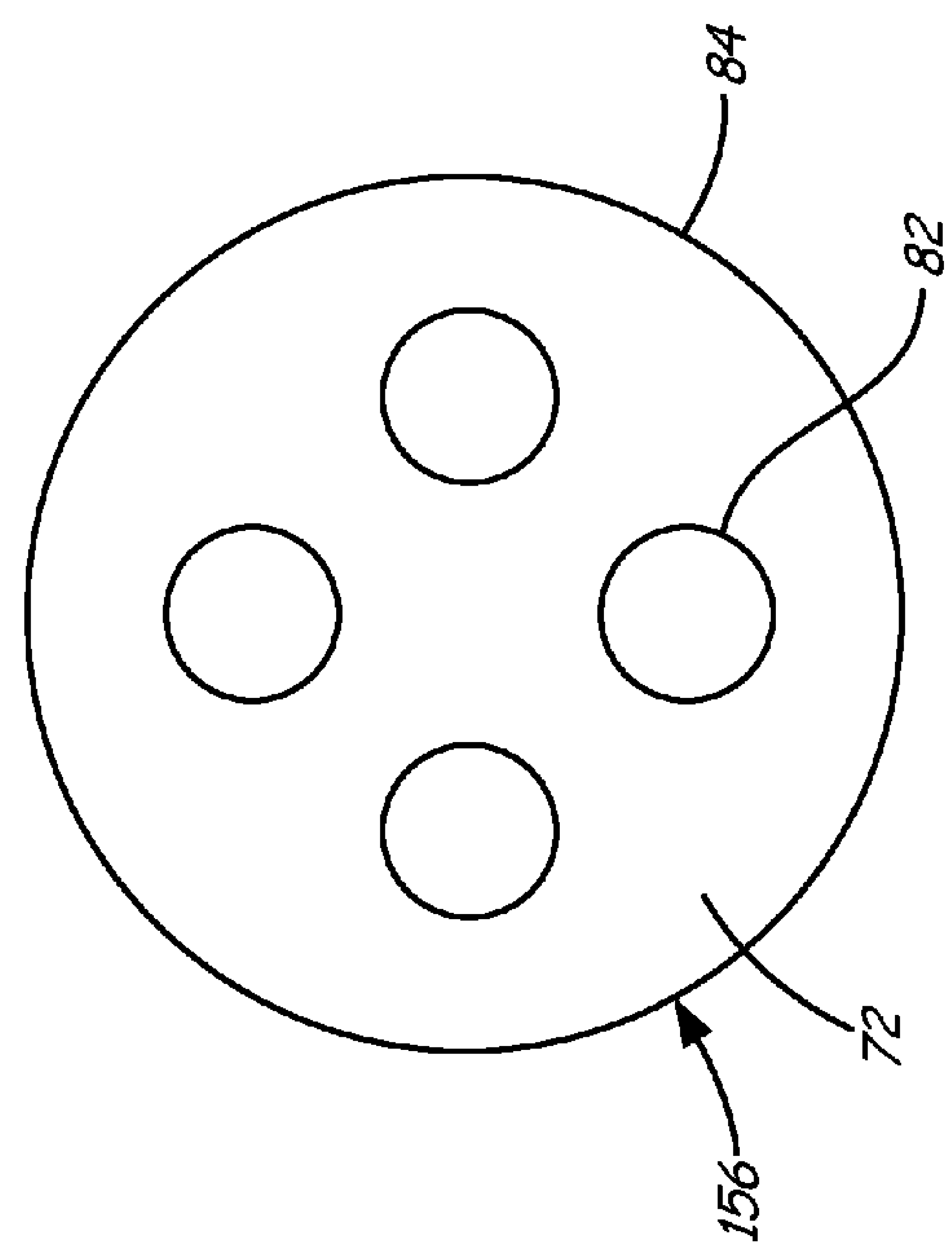

Fig. 4

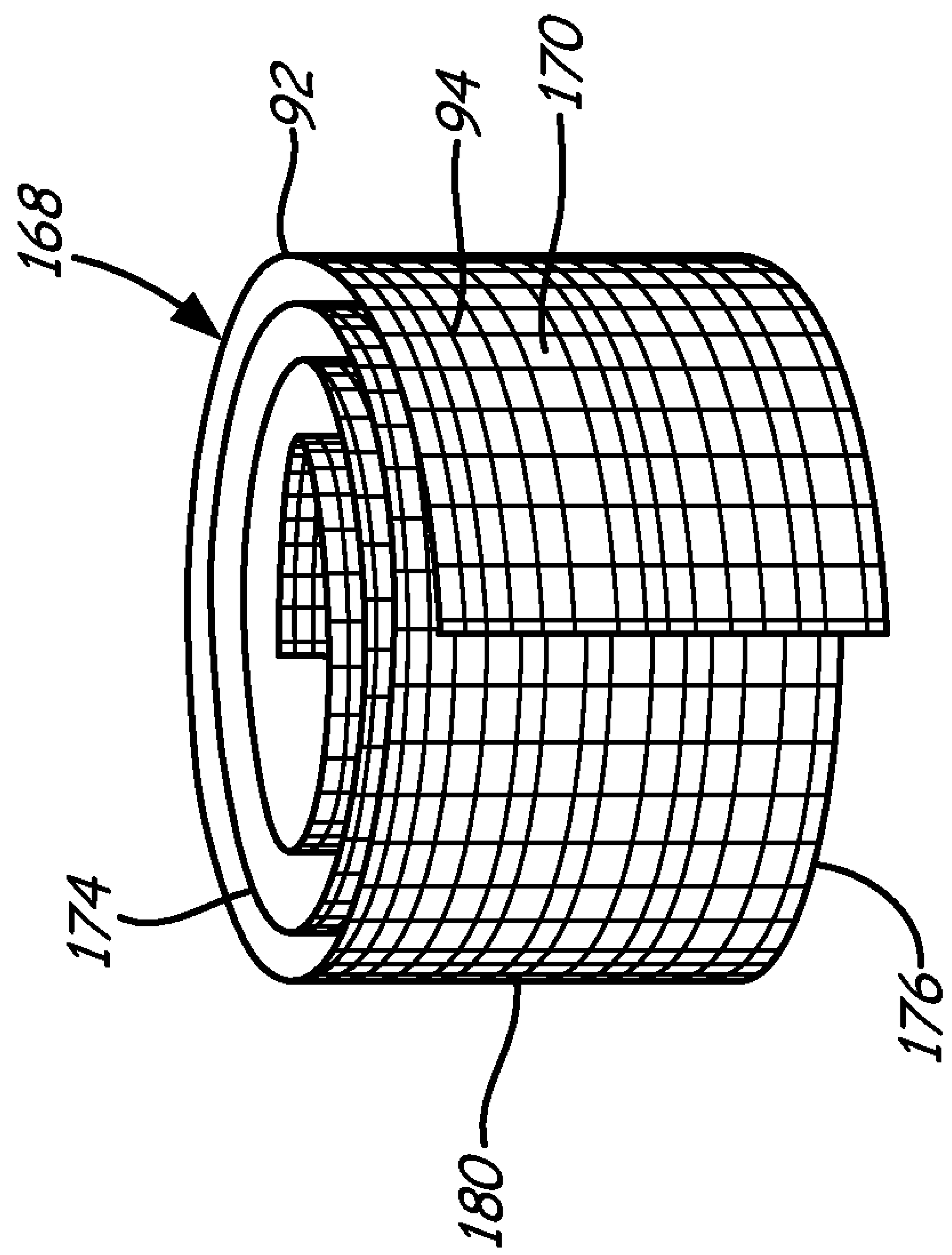

Fig. 6B

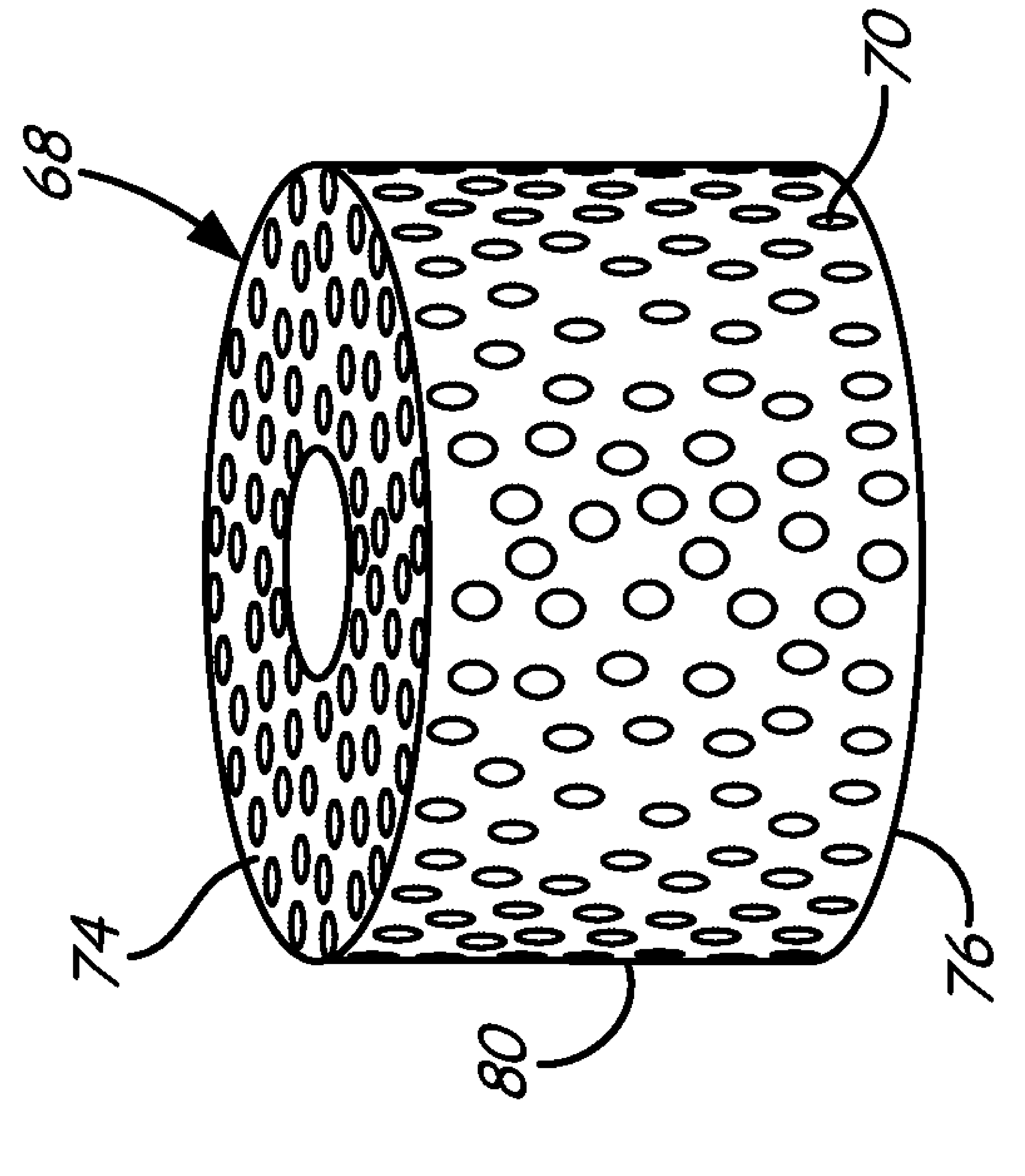

Fig. 6A

ANTI-ROTATION DEAERATOR OUTLET DIFFUSER

BACKGROUND

The present invention relates to lubrication systems, and in particular, to a deaerator for a lubrication system.

Certain lubrication systems function in a way that allows air to enter and be mixed with flow of lubricating liquid. Because it can be undesirable to have air in the lubricating liquid, deaerators are often used to separate air from lubricating liquid. For example, in gas turbine engines, lubrication systems typically use a deaerator to separate a scavenged mixture of air and lubricating liquid and to return the lubricating liquid to a reservoir for later use. It is desirable for the deaerator to supply the lubricating liquid to the reservoir with few or no air bubbles entrained in the lubricating liquid.

However, if the lubricating liquid leaves the deaerator at a relatively fast speed, that flow of lubricating liquid can agitate the surface of the lubricating liquid already in the reservoir, undesirably adding air bubbles to the lubricating liquid. A deaerator can be designed large enough that the lubricating liquid moves relatively slowly when it leaves the deaerator, but a large deaerator adds undesirable weight and also takes up valuable space.

SUMMARY

According to one embodiment of the present invention, a lubrication system includes a reservoir having an interior cavity for holding lubricating liquid and a deaerator positioned at least partially inside the interior cavity. The deaerator includes a vortex regulator plate dividing the deaerator into a vortex chamber and a diffuser chamber and a porous diffuser substantially filling the diffuser chamber.

Another embodiment of the present invention is a deaerator includes a case defining a vortex chamber, a fluid inlet for allowing a mixture of lubricating liquid and air to pass through the case into the vortex chamber, an air outlet for allowing air flow out of the deaerator, and a liquid outlet for allowing lubricating liquid flow out of the deaerator. A porous diffuser is positioned proximate the liquid outlet. A plate is positioned adjacent the porous diffuser and has a first surface in contact with the porous diffuser.

Another embodiment of the present invention is a method of deaerating a lubricating liquid. The method includes flowing a mixture of lubricating liquid and air from a plurality of gas turbine engine components into a vortex chamber of a deaerator, separating air from lubricating liquid in the vortex chamber, flowing separated lubricating liquid through a porous diffuser to a lubricating liquid reservoir, limiting rotation of the porous diffuser by pressing the porous diffuser between two surfaces, and flowing separated air through an air outlet to flow out of the deaerator, bypassing the porous diffuser.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view of a gas turbine engine having a lubrication system.

FIG. **2** is a perspective sectional view of a reservoir and deaerator of the lubrication system of FIG. **1**.

FIG. **3** is a perspective sectional view of an embodiment of the deaerator of FIG. **2**.

FIG. **4** is a bottom view of an alternative embodiment of a vortex regulator plate for use in the deaerator of FIGS. **1-3**.

FIG. **5**A is a bottom view of another alternative embodiment of a vortex regulator plate for use in the deaerator of FIGS. **1-3**.

FIG. **5**B is a side view of the vortex regulator plate of FIG. **5**A.

FIG. **6**A is a perspective view an embodiment of a diffuser for use with the deaerator of FIGS. **1-3**.

FIG. **6**B is a perspective view of another embodiment of a diffuser for use with the deaerator of FIGS. **1-3**.

DETAILED DESCRIPTION

FIG. **1** is a schematic view of gas turbine engine **10** having lubrication system **12**. Lubrication system **12** includes reservoir **14**, deaerator **16**, supply passage **18**, scavenge passage **20**, supply pump **22**, and scavenge pump **24**. Supply pump **22** pumps a lubricating liquid, such as oil, from reservoir **14** to engine components **26**A and **26**B to cool and lubricate engine components **26**A and **26**B. Engine components **26**A and **26**B can be virtually any components on gas turbine engine **10** that benefit from lubricating liquid, such as gears and bearings. Scavenge pump **24** pumps lubricating liquid from engine components **26**A and **26**B and returns it to deaerator **16** in reservoir **14**. Scavenge pump **24** can be sized and configured so as to scavenge air in engine components **26**A and **26**B in addition to the lubricating liquid. Consequently, a mixture of lubricating liquid and air is passed through fluid inlets **28** of deaerator **16**.

Deaerator **16** separates the lubricating liquid from the air, passing the air out through air outlet **30** to the exterior of reservoir **14** and passing the lubricating liquid thorough liquid outlets **32** to interior cavity **34** of reservoir **14**. Interior cavity **34** is defined by reservoir wall **36**.

In the illustrated embodiment, deaerator **16** has a substantially cylindrical shape. Air outlet **30** is a single outlet on a top of deaerator **16**. Fluid inlets **28** include four inlets (one of which is shown in FIG. **1**) equally spaced around a perimeter of deaerator **16** near the top of deaerator **16**. Fluid inlets **28** are arranged and shaped to impart high speed rotation of the air and oil mixture inside of deaerator **16**. Liquid outlets **32** include four outlets (two of which are shown in FIG. **1**) equally spaced around a perimeter of deaerator **16** near a bottom of deaerator **16**. In alternative embodiments, deaerator **16** can have a different shape, and air outlet **30**, fluid inlets **28**, and liquid outlets **32** can be included in different numbers and positions as suitable for a particular application. Moreover, lubrication system **12** can also be different, having one or more additional or different connections or components, such as valves, filters, sensors, heat exchangers, etc.

FIG. **2** is a perspective sectional view of reservoir **14** and deaerator **16**. Deaerator **16** is installed in socket **40** of reservoir **14** and held in place by retaining ring **42**. In the illustrated embodiment, deaerator **16** is positioned substantially inside interior cavity **34** of reservoir **14**. In an alternative embodiment, deaerator **16** can be positioned only partially inside interior cavity **34** of reservoir **14**.

O-rings **44**A and **44**B provide seals between socket **40** and cylindrical case **46** of deaerator **16**. Cylindrical case **46** of deaerator **16** is held substantially stationary with respect to reservoir **14**. Inlet plenum **48** is positioned between socket **40** and case **46**, sealed by o-ring **44**A on top and o-ring **44**B on bottom. Inlet plenum **48** receives the mixture of air and lubricating liquid from scavenge passage **20** prior to flowing it through fluid inlets **28** and into vortex chamber **50**. Vortex chamber **50** is bounded and defined by inner surface **52** of case **46**. Vortex regulator plate **56** is positioned in vortex chamber **50** between fluid inlet **28** and liquid outlet **32**. Vortex chamber **50** is divided from diffuser chamber **54** by vortex regulator plate **56**. Vortex chamber **50** is a top chamber above vortex regulator plate **56**, and diffuser chamber **54** is a bottom chamber below vortex regulator plate **56**. Deaerator top **58** provides a top for deaerator **16** and for vortex chamber **50**. Deaerator bottom **60** provides a bottom for deaerator **16** and diffuser chamber **54**. A radial gap between vortex regulator plate **56** and inner surface **52** allows a space for liquid flow from fluid inlets **28** to liquid outlets **32**. Vortex regulator plate **56** limits air flow from fluid inlets **28** to liquid outlets **32**. Air passage **62** is a substantially cylindrical passage positioned in a center of vortex chamber **50** and includes air inlets **64**. Air inlets **64** allow air to flow from vortex chamber **50** through air passage **62** and out air outlet **30**. Air passage **62** and vortex regulator plate **56** are spaced from deaerator bottom **60** by center support **66**.

Diffuser **68** is positioned in diffuser chamber **54**. Diffuser **68** is a porous diffuser, having pores **70**. In the illustrated embodiment, diffuser **68** fills substantially all of the space in diffuser chamber **54** between deaerator bottom **60** and vortex regulator plate **56**. Diffuser **68** has a substantially toroidal shape, with center support **66** positioned in a center of diffuser **68**.

In operation, the mixture of lubricating liquid and air flows from scavenge passage **20**, through inlet plenum **48**, and through fluid inlets **28** into vortex chamber **50**. Fluid inlets **28** are angled and aligned substantially tangentially with inner surface **52** of case **46** so as to induce vortex flow in vortex chamber **50**. This vortex flow is induced without having to spin deaerator **16**, which is substantially stationary with respect to the vortex flow within. The vortex flow separates the mixture of air and lubricating liquid, thus forcing separated air toward a center of vortex chamber **50** and forcing separated lubricating liquid toward a perimeter of vortex chamber **50**. The separated air flows through air inlets **64**, through air passage **62**, and out air outlet **30** to a space outside of deaerator **16** and reservoir **14**. Air flows directly from vortex chamber **50** to air passage **62**, bypassing diffuser chamber **54** and diffuser **68**. The separated lubricating liquid flows through the space between vortex regulator plate **56** and inner surface **52**, into diffuser chamber **54**, thorough diffuser **68**, and then out liquid outlets **32** into interior cavity **34** of reservoir **14**.

Parts of deaerator **16**, including fluid inlets **28** and vortex chamber **50**, can be sized and shaped to cause relatively fast fluid flow in vortex chamber **50**. This causes the separated lubricating liquid passing through the space between vortex regulator plate **56** and inner surface **52** of case **46** to also flow relatively fast. The porous structure of diffuser **68** can slow the flow of the separated lubricating liquid as it passes through diffuser **68**. This allows deaerator **16** to deliver separated lubricating liquid to reservoir **14** at a relatively slow flow speed. This can be particularly beneficial in situations where the liquid level in reservoir **14** is at or below liquid outlets **32**. In such situations, a relatively fast flow of lubricating liquid from deaerator **16** could agitate the surface of the lubricating liquid in reservoir **14**, undesirably adding air bubbles to the lubricating liquid in reservoir **14**. Thus, use of diffuser **68** to reduce flow speed results in a reduced risk of agitation and a reduced risk of adding air bubbles. Because diffuser **68** can reduce such flow speeds, it allows for deaerator **16** to be designed as a relatively small and high speed deaerator. This can result in weight and space savings.

For example, deaerator **16** can be designed with a length to diameter ratio less than 7:1, such as about 4:1. In the illustrated embodiment, deaerator **16** has a diameter of about 2 inches (about 5 centimeters) and a height of about 8 inches (about 20 centimeters). Diffuser **68** also has a diameter of about 2 inches (about 5 centimeters) and a height of about 0.5 inches (about 1.3 centimeters). In alternative embodiments, deaerator **16** and diffuser **68** can have different sizes and shapes as suitable for a particular application.

FIG. **3** is a perspective sectional view of one embodiment of deaerator **16**. Because of the relatively fast fluid flow in vortex chamber **50**, that fluid can create a force on diffuser **68** tending to rotate diffuser **68** in diffuser chamber **54**. If diffuser **68** were allowed to rotate, the effectiveness of diffuser **68** could be reduced. Diffuser **68** can be both deformable and resilient. As illustrated in FIG. **3**, vortex regulator plate **56** is positioned adjacent diffuser **68** such that plate bottom surface **72** abuts diffuser top surface **74**. Plate bottom surface **72** presses diffuser **68** against deaerator bottom **60**, such that diffuser bottom surface **76** abuts surface **78** of deaerator bottom **60**. Thus, diffuser **68** is in friction contact with plate bottom surface **72** and with surface **78** of deaerator bottom **60**. This friction contact can create a force to resist rotation of diffuser **68** in response to the force of the relatively fast fluid flow.

When vortex regulator plate **56** presses against diffuser **68**, it can cause diffuser **68** to compress in an axial direction (along center support **66**) and expand in a radial direction (radially outward from center support **66**). Diffuser side surface **80** is adjacent inner surface **52** of case **46**. Diffuser side surface **80** is sufficiently close to inner surface **52** that when vortex regulator plate **56** presses against diffuser **68**, radial expansion of diffuser **68** presses diffuser side surface **80** against inner surface **52** so as to be in friction contact. This friction contact can create an additional force to resist rotation of diffuser **68** in response to the force of the relatively fast fluid flow.

One of liquid outlets **32** is illustrated in FIG. **3** in phantom, behind diffuser **68**. When vortex regulator plate **56** presses against diffuser **68**, it can also cause diffuser **68** to expand into one or more of liquid outlets **32**, creating a bulge of diffuser **68** in liquid outlets **32**. This bulge of diffuser **68** can resist rotation of diffuser **68** in response to the force of the relatively fast fluid flow.

FIG. **4** is a bottom view of vortex regulator plate **156** in an embodiment, which is similar to vortex regulator plate **56** of FIGS. **2-3**, except vortex regulator plate **156** has plate holes **82**. Plate holes **82** are spaced radially inward from circumferential edge **84** of vortex regulator plate **156**. When vortex regulator plate **156** presses against diffuser **68** (shown in FIGS. **2-3**), it can also cause diffuser **68** to expand into one or more of plate holes **82**, creating a bulge of diffuser **68** in plate holes **82**. This bulge of diffuser **68** can resist rotation of diffuser **68** in response to the force of the relatively fast fluid flow.

FIG. **5**A is a bottom view of vortex regulator plate **256** in an embodiment, which is similar to vortex regulator plate **56** of FIGS. **2-3**, except vortex regulator plate **256** has plate ridge **86**. Plate ridge **86** is a projection extending from plate bottom surface **72** of vortex regulator plate **256**. Plate ridge **86** extends across vortex regulator plate **256** from first ridge end **88** to second ridge end **90**. First ridge end **88** and second ridge end **90** are each substantially adjacent circumferential edge **84**. When vortex regulator plate **256** presses against diffuser **68** (shown in FIGS. **2-3**), plate ridge **86** compresses diffuser **68**, causing an indentation in diffuser **68**. Thus, plate ridge **86** can resist rotation of diffuser **68** in response to the force of the relatively fast fluid flow. In alternative embodiments, plate ridge **86** can be replaced by one or more other projections that extend toward and compress diffuser **68**. In further alternative embodiments, vortex regulator plates **56**, **156**, and **256** can include one or more other features that help resist rotation of diffuser **68**.

FIG. **5**B is a side view of vortex regulator plate **256**. FIG. **5**B illustrates plate ridge **86** extending from plate bottom surface **72**.

FIG. **6**A is a perspective view of an embodiment of diffuser **68** for use with deaerator **16**. In the embodiment of FIG. **6**A, diffuser **68** is a metal mesh foam having numerous pores **70**. Pores **70** are interconnected, allowing and slowing flow through the foam material of diffuser **68**. The embodiment of diffuser **68** shown in FIG. **6**A is substantially the same as that illustrated in FIGS. **2** and **3**.

FIG. **6**B is a perspective view of diffuser **168** in an embodiment, which is similar to diffuser **68** of FIG. **6**A, except diffuser **168** is made from wire screen **92** rolled in a spiral shape, which can be seen when viewing diffuser top surface **174** or diffuser bottom surface **176**. When wire screen **92** is rolled in a spiral shape, it effectively results in diffuser **168** having a substantially toroidal shape. Wire screen **92** includes a matrix of crossing wires **94**, which can be seen viewing diffuser side surface **180**. When wire screen **92** is rolled in a spiral shape, diffuser **168** effectively has numerous interconnected pores **170**, allowing and slowing flow through diffuser **168**. The embodiment of diffuser **168** shown in FIG. **6**B is sized and shaped to replace diffuser **68** as illustrated in FIGS. **2** and **3**.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the appended claims. For example, a diffuser need not necessarily be made of a metal mesh foam or a wire screen, but could in other embodiments be made of another suitably porous material.

The invention claimed is:

1. A lubrication system, comprising:
- a reservoir having an interior cavity for holding lubricating liquid; and
- a deaerator positioned at least partially inside the interior cavity, the deaerator comprising:
  - a vortex regulator plate dividing the deaerator into a vortex chamber and a diffuser chamber; and
  - a porous diffuser substantially filling the diffuser chamber.

2. The lubrication system of claim **1**, and further comprising:
- a supply passage connecting the reservoir to a supply pump;
- a scavenge passage connecting a scavenge pump to a fluid inlet of the vortex chamber; and
- a plurality of gas turbine engine components connected to both the supply pump and the scavenge pump via the supply passage and the scavenge passage, respectively.

3. The lubrication system of claim **1**, wherein the porous diffuser is compressed between the vortex regulator plate and a bottom of the deaerator.

4. A deaerator, comprising:
- a case defining a vortex chamber;
- a fluid inlet for allowing a mixture of lubricating liquid and air to pass through the case into the vortex chamber;
- an air outlet for allowing air flow out of the deaerator;
- a liquid outlet for allowing lubricating liquid flow out of the deaerator;
- a porous diffuser positioned proximate the liquid outlet; and
- a plate positioned adjacent the porous diffuser and having a first surface in contact with the porous diffuser.

5. The deaerator of claim **4**, wherein the plate comprises:
- a vortex regulator plate positioned in the vortex chamber between the fluid inlet and the liquid outlet.

6. The deaerator of claim **5**, wherein the vortex regulator plate limits air flow from the fluid inlet to the liquid outlet and wherein a radial gap between the vortex regulator plate and an inner surface of the case allows liquid flow from the fluid inlet to the liquid outlet.

7. The deaerator of claim **5**, wherein the porous diffuser is compressed between the vortex regulator plate and a bottom of the deaerator.

8. The deaerator of claim **7**, wherein the case is substantially cylindrical, and wherein the porous diffuser is compressed against the case.

9. The deaerator of claim **4**, wherein the plate comprises a hole and wherein the porous diffuser bulges into the hole.

10. The deaerator of claim **4**, wherein the porous diffuser bulges into the liquid outlet due to compressive force exerted by the plate.

11. The deaerator of claim **4**, wherein the plate comprises:
- a projection extending from the plate and compressing the porous diffuser.

12. The deaerator of claim **11**, wherein the plate is substantially disk shaped with a circumferential edge, wherein the projection is a ridge extending across the plate from a first ridge end adjacent the circumferential edge to a second ridge end adjacent the circumferential edge.

13. The deaerator of claim **4**, wherein the porous diffuser comprises a metal mesh foam.

14. The deaerator of claim **4**, wherein the porous diffuser comprises a wire screen rolled in a spiral shape.

15. A method of deaerating a lubricating liquid, the method comprising:
- flowing a mixture of lubricating liquid and air from a plurality of gas turbine engine components into a vortex chamber of a deaerator;
- separating air from lubricating liquid in the vortex chamber;
- flowing separated lubricating liquid through a porous diffuser to a lubricating liquid reservoir;
- limiting rotation of the porous diffuser by pressing the porous diffuser between two surfaces; and
- flowing separated air through an air outlet to flow out of the deaerator, bypassing the porous diffuser.

16. The method of claim **15**, wherein rotation of the porous diffuser is limited due to friction between the porous diffuser and the two surfaces.

17. The method of claim **15**, wherein rotation of the porous diffuser is limited due to friction between the porous diffuser and a third surface, wherein the third surface comprises an inner surface of a case of the deaerator.

18. The method of claim **15**, wherein pressing the porous diffuser causes a portion of the porous diffuser to bulge into a hole.

19. The method of claim **18**, wherein the first surface is a surface of a vortex regulator plate and wherein the hole extends through the vortex regulator plate.

20. The method of claim **18**, wherein the hole is a liquid outlet extending through a cylindrical case of the deaerator.

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